AMENDMENTS TO THE CLAIMS

1-123. (Cancelled)

124. (Original) A method of sensing photons comprising:

receiving said photons into a trench, said trench disposed in a doped layer of a first conductivity type formed in a semiconductor substrate;

activating a diode formed in said substrate adjacent said trench by absorbing said photons, said diode including a first doped region of a second conductivity type formed in a sidewall and bottom of said trench;

receiving charges from said first doped region into a second doped region of said second conductivity type formed in said doped layer; and

resetting a charge level of said second doped region by receiving charges from said second doped region into a conductive signal line .

125. (Original) A method of sensing photons as defined in claim 124 wherein said resetting a charge level of said second doped region comprises transferring charges through a reset transistor.

126. (Original) A method of sensing photons as defined in claim 125 wherein said reset transistor includes a drain region and a gate and wherein said second doped region includes a source of said reset transistor.

127. (Original) A method of sensing photons as defined in claim 124 wherein receiving said photons into said trench comprises receiving said photons through an aperture in an upper surface of said semiconductor substrate.

128. (Original) A method of sensing photons as defined in claim 124 wherein activating said diode comprises energizing electrons in response to absorbing said photons into said semiconductor substrate.

129. (Original) A method of sensing photons as defined in claim 124 wherein activating said diode comprises absorbing said photons in a first region of a surface of said trench after reflecting said photons from a second region of said surface of said trench.

130. (Original) A method of sensing photons as defined in claim 124 wherein activating said diode comprises:

conducting said photons through a transparent layer disposed above an internal surface of said trench; and

absorbing said photons into said semiconductor substrate.

131. (Original) A method of sensing light comprising:

receiving said light through an aperture in a surface of a semiconductor substrate;

absorbing said light into an internal surface of said semiconductor substrate, said internal surface defining a cavity within said semiconductor substrate;

energizing an electron of said semiconductor substrate with said absorbed light; and

activating a switching device using said energized electron.

132. (Original) A method of sensing light as defined in claim 131 wherein said activating a switching device comprises activating a field effect transistor.

133. (Original) A method of sensing light as defined in claim 131 wherein said absorbing said light into said internal surface comprises receiving said light into said substrate through a layer of conductive material.

134. (Original) A method of sensing light as defined in claim 133 wherein said layer of conductive material comprises a photo-gate said method including applying an electrical potential to said photo-gate.

135. (Original) A method of sensing light as defined in claim 131 wherein said absorbing said light into said internal surface comprises receiving said light into said substrate through a layer of insulating material.

136. (Original) A method of sensing light as defined in claim 131 wherein said absorbing said light into said internal surface comprises receiving said light through a first region of substrate material having a first doping characteristic into a second region of substrate material having a second doping characteristic.

137. (Original) A method of sensing light as defined in claim 131 wherein said switching device includes a field effect transistor and wherein said activating a switching device using said energized electron comprises:
passing said energized electron through a first transistor to a floating diffusion region; and elevating an electrical potential of a gate of said field effect transistor, said gate being electrically coupled to said floating diffusion region.

138. (Original) A method of sensing photon flux comprising:

receiving a first plurality of photons at a bottom surface of a trench photo-capacitor and forming a first plurality of photo-electrons;

receiving a second plurality of photons at a side surface of said trench photo-capacitor and forming a second plurality of photo-electrons; and

generating an output signal related to said first and second pluralities of photo-electrons.

139. (Original) A method of sensing photon flux as defined in claim 138 wherein said generating an output signal comprises:

switchingly transferring photo-electrons of said first and second pluralities of photo-electrons from a region proximate said trench photo-capacitor to a floating diffusion region.

140. (Original) A method of sensing photon flux as defined in claim 139 further comprising:

elevating an electrical potential of said floating diffusion region in relation to said photo-electrons of said first and second pluralities; and

controlling a transistor having a gate coupled to said floating diffusion region in relation to said elevated electrical potential.

141-144. (Cancelled)

145. (Original) A method of controlling photo-generated charge carriers comprising:

receiving a flux of photons at a photo-active surface of a photosensor;

photo-generating charge carriers with said flux of photons;

storing said charge carriers in a trench capacitor;

conducting said charge carriers through a transfer gate channel to a floating diffusion node, said floating diffusion node being electrically coupled to a transistor gate;

conducting said charge carriers from said floating diffusion node to said transistor gate; and

conducting said charge carriers from said transistor gate through a reset gate channel to a supply conductor.

146. (Original) A method of controlling photo-generated charge carriers as defined in claim 145 wherein said photo-generated charge carriers comprise photo-generated electrons.

147. (Original) A method of controlling photo-generated charge carriers as defined in claim 145 wherein said receiving a flux of photons at a photo-active surface comprises:

receiving said flux of photons at a photo-active surface disposed at a surface of said trench capacitor.

148. (Original) A method of controlling photo-generated charge carriers as defined in claim 145 wherein said conducting said charge carriers through a transfer gate channel comprises:

receiving an electronic transfer signal at a transfer gate disposed above said transfer gate channel.

149. (Original) A method of controlling photo-generated charge carriers as defined in claim 145 wherein said conducting said electrons through a reset gate channel to a supply conductor comprises:

receiving an electronic reset signal at a reset gate disposed above said reset gate channel.

150. (Original) A method of controlling photo-generated charge carriers as defined in claim 145 wherein said trench capacitor comprises a cavity formed through an upper surface of a doped semiconductor substrate, said cavity having an internal surface and photo-gate disposed above at least a portion of said inner surface.

151. (Original) A method of controlling photo-generated charge carriers as defined in claim 150 wherein said photo-gate comprises a layer of conductive material and wherein said trench capacitor includes a layer of insulating material disposed between said layer of conductive material and said internal surface.

152. (Original) A method of controlling photo-generated charge carriers as defined in claim 151 wherein said storing said photo-generated charge carriers in said trench capacitor comprises applying an electrical potential to said photo gate.

153. (Original) A method of controlling photo-generated charge carriers as defined in claim 150 wherein said trench capacitor comprises a doped well disposed within said doped semiconductor substrate, said cavity being disposed within said doped well.

154. (Original) A method of controlling photo-generated charge carriers as defined in claim 145 wherein said trench capacitor comprises a cavity formed through an upper surface of a doped semiconductor substrate, said cavity having an internal surface and a doped region within said semiconductor substrate adjacent said internal surface.

155. (Original) A method of controlling photo-generated charge carriers as defined in claim 154 wherein said storing said photo-generated charge carriers in said trench capacitor comprises storing photo-electrons in a region of said doped semiconductor substrate outside of said doped region.

156. (Original) A method of controlling photo-generated charge carriers as defined in claim 154 wherein one of said doped substrate and doped region are doped to be n-type material and the other of said doped substrate and doped region are doped to be p-type material.

157. (Original) A method of controlling photo-generated charge carriers as defined in claim 154 wherein said cavity comprises a substantially cylindrical cavity.

158. (Original) A method of controlling photo-generated charge carriers as defined in claim 154 wherein said internal surface of said cavity includes a substantially vertical sidewall region and a bottom region.

159. (Original) A method of controlling photo-generated charge carriers as defined in claim 145 wherein said transistor gate comprises a gate of a source follower transistor.

160. (Original) A method of controlling photo-generated charge carriers as defined in claim 159 further comprising:

receiving electrical current through said source follower transistor at respective inputs of a first reset sample and hold circuit and of second signal sample and hold circuit;

sampling said current into said first reset sample and hold circuit during a first time interval to store a reset value; and

sampling said current into said second signal sample and hold circuit during a second signal time interval to store a signal value.

161. (Original) A method of controlling photo-generated charge carriers as defined in claim 160 wherein said second time interval precedes said first time interval.

162. (Original) A method of controlling photo-generated charge carriers as defined in claim 160 further comprising:

receiving said reset value and said signal value at respective reset and signal inputs of a subtraction circuit and producing a difference output signal related to a difference between said reset and signal values.

163. (Original) A method of controlling photo-generated charge carriers as defined in claim 162 further comprising:

receiving said difference signal at an input of a column driver circuit of an integrated circuit imaging device;

receiving a control signal at said column driver circuit from a column decoder circuit of said integrated circuit imaging device; and

receiving said difference signal through said column driver circuit at an analog to digital converter circuit of said integrated circuit imaging device.

164. (Original) A method of controlling photo-generated charge carriers as defined in claim 160 wherein said receiving electrical current through said source follower transistor further comprises receiving said electrical current through a row select transistor coupled in series with said source follower transistor;

receiving a row select signal at a gate of said row select transistor from a row driver to control said electrical current; and

activating said row driver to produce said row select signal in response to an activation signal of a row decoder circuit.

165. (Original) A method of controlling photo-generated charge carriers as defined in claim 164 wherein said activating said row driver comprises receiving an address signal over an address bus of an integrated circuit imaging device.

166. (Original) A method of controlling photo-generated charge carriers as defined in claim 145 further comprising maintaining said supply conductor at a reset voltage.

167. (Original) A method of signaling to a photosensor to control operation of said photosensor, said method comprising:

during a first time interval receiving a reset signal at a reset gate disposed above a reset gate channel, said reset gate channel being disposed within a substrate, said reset gate conducting a current between a floating diffusion node disposed within said substrate and a source of reset potential, said reset sample and hold circuit adapted to sample a voltage of said floating diffusion node during said second time interval;

during a second time interval receiving a reset value sample and hold signal at a reset sample and hold circuit coupled, said floating diffusion node being coupled to a gate of a source follower transistor and to a trench capacitor;

during a third time interval, receiving a photo-gate sample and hold signal at a photo-gate disposed above the photo-active surface of said photosensor said photo-active surface being disposed within said trench capacitor; and

during a fourth time interval receiving a signal value sample and hold signal at a signal sample and hold circuit, said signal sample and hold circuit being adapted to sample a voltage of said floating diffusion node during said fourth time interval.

168. (Original) A method of signaling to a photosensor to control operation of said photosensor as defined in claim 167 further comprising:

during a fifth time interval receiving a transfer signal at a transfer gate disposed above a transfer gate channel, said transfer gate channel disposed within said substrate, said transfer gate channel switchingly coupling trench capacitor to said floating diffusion node.

169. (Original) A method of signaling to a photosensor to control operation of said photosensor as defined in claim 168 wherein said fifth time interval occurs between said third and fourth time intervals.

170. (Original) A method of converting an optical signal to an electrical signal comprising:

receiving said optical signal at a surface of a photoreceptor;

absorbing said optical signal through said surface of said photoreceptor;

energizing a plurality of electrons with said optical signal in relation to an intensity of said optical signal;

storing said plurality of energized electrons in a substantially concave distribution within a substrate and thereby adjusting an electrical potential of a corresponding substantially concave region within said substrate, said substrate supporting said photoreceptor; and

adjusting an electrical output signal of an output circuit in relation to a magnitude of said electrical potential.

171. (Original) A method of converting an optical signal to an electrical signal as defined in claim 170 wherein said substantially concave region within said substrate comprises a region disposed about a surface of a cavity within said substrate.

172. (Original) A method of converting an optical signal to an electrical signal as defined in claim 171 wherein said surface of said cavity comprises a substantially cylindrical surface.

173. (Original) A method of converting an optical signature to an electric signal as defined in claim 171 wherein said surface of said cavity comprises a substantially rectangular surface.

174. (Original) A method of converting an optical signal to an electrical signal as defined in claim 171 wherein said surface of said photoreceptor and said surface of said cavity are substantially coextensive.

175. (Original) A method of converting an optical signal to an electrical signal as defined in claim 171 wherein said substrate includes a further doped region adjacent to said internal surface of said cavity, said substantially concave region being disposed adjacent said further doped region such that said further doped region is located between said substantially concave region and said surface of said cavity.

176. (Original) A method of converting an optical signal to an electrical signal as defined in claim 170 further comprising:

receiving said electrical potential at a gate of a transistor disposed within said output circuit; and

receiving said electrical output signal through said transistor at an output node of said output circuit.

177. (Original) A method of converting an optical signal to an electrical signal as defined in claim 176 wherein receiving said electrical output signal through said transistor includes receiving an analog current signal, said method further comprising:

receiving said analog current signal at an input of an analog to digital converter and;

converting said analog current signal to a digital signal in said analog to digital converter.

178. (Original) A method of converting an optical signal to an electrical signal as defined in claim 177 wherein said converting said analog current signal to a digital signal in said analog to digital converter comprises:

receiving said analog current signal at an input of a sample and hold circuit;

sampling said analog current signal; and

digitizing said analog current signal to produce a digital output signal.

179. (Original) A method of converting an optical signal to an electrical signal as defined in claim 178 further comprising:

storing said digital output signal in a digital electronic memory.

180. (Original) A method of converting an optical signal to an electrical signal as defined in claim 179 wherein said photoreceptor, said analog to digital converter, and said digital electronic memory are all disposed on said substrate.

181. (Original) A method of converting an optical signal to an electrical signal as defined in claim 170 wherein said adjusting said output electrical signal of an output circuit comprises receiving a plurality of said energized electrons at a floating diffusion node disposed within said substrate from said concave region.

182. (Original) A method of converting an optical signal to an electrical signal as defined in claim 181 wherein said receiving said plurality of energized electrons at said floating diffusion node from said substantially concave region comprises:

receiving said plurality of energized electrons at said floating diffusion node through a transfer gate region of said substrate; and

controlling a conductivity of said transfer gate region of said substrate by adjusting an electrical potential of a conductive transfer gate disposed above said transfer gate region of said substrate.

183. (Original) A method of converting an optical signal to an electrical signal as defined in claim 181 further comprising:

resetting an electrical potential of said floating diffusion node by switchingly coupling said floating diffusion node to a source of substantially constant electrical potential.

184. (Original) A method of converting an optical signal to an electrical signal as defined in claim 170 wherein said receiving said optical signal comprises receiving an electromagnetic signal including visible spectrum light.

185. (Original) A method of converting an optical signal to an electrical signal as defined in claim 170 wherein said absorbing said optical signal through said surface of said photoreceptor comprises absorbing said optical signal through a layer of insulating material disposed above a surface of said substrate.

186. (Original) A method of converting an optical signal to an electrical signal as defined in claim 170 wherein said absorbing said optical signal through said surface of said photoreceptor comprises absorbing said optical signal through a layer of conductive material disposed above a surface of said substrate.

187. (Original) A method of converting an optical signal to an electrical signal as defined in claim 186 wherein said layer of conductive material comprises a metallic material.

188. (Original) A method of converting an optical signal to an electrical signal as defined in claim 186 wherein said layer of conductive material comprises a photo-gate.

189. (Original) A method of capturing an image comprising:

receiving said image at an array of pixel devices, said pixel devices including a plurality of apertures disposed in a surface of a substrate and a plurality of cavities disposed within said substrate beneath said plurality of apertures respectively;

charging a plurality of capacitors to a respective plurality of electrical potentials, said capacitors being disposed adjacent said plurality of cavities respectively, said plurality of electrical potentials related light flux of said image at said respective apertures;

receiving charge from said plurality of capacitors at a respective plurality of transistors;

receiving a plurality of electrical signals from said plurality of transistors respectively; and

recording said plurality of electrical signals to capture said image.

190. (Original) A method of capturing an image as defined in claim 189 further comprising:

converting said plurality of electrical signals to a plurality of digital signals.

191. (Original) A method of capturing an image as defined in claim 189 wherein said recording said plurality of electrical signals comprises storing digital data in a memory device.

192. (Original) A method of capturing an image as defined in claim 191 further comprising performing digital signal processing on said digital data.

193. (Original) A method of capturing an image as defined in claim 191 wherein said plurality of apertures are disposed in substantially planar relation to one another.

194. (Original) A method for operating a digital image acquisition system comprising:

receiving an optical image at a CMOS image sensor array, said array including a plurality of photosensors and a respective plurality of controllable transistors, said plurality

of photosensors including a respective plurality of trench capacitors, each said trench capacitor having a photosensitive region on a wall thereof;

sensing a plurality of charge values stored on said plurality of trench capacitors respectively; and

producing a plurality of output signals related to said plurality of charge values respectively.

195. (Original) A method for operating a digital image acquisition system as defined in claim 194 wherein said producing a plurality of output signals comprises producing a plurality of digital values, said digital values related to an intensity of light incident at said plurality of trench capacitors respectively.

196. (Original) A method for operating a digital image acquisition system as defined in claim 195 further comprising receiving said plurality of digital values at a digital memory.

197. (Original) A method for operating a digital image acquisition system as defined in claim 196 further comprising retrieving said plurality of digital values from said digital memory into a digital processor.

198. (Original) A method for operating a digital image acquisition system as defined in claim 197 further comprising receiving an image signal at an image display device from said the coprocessor, said image signal related to said plurality of digital values; and

display and output image on said image display device, said output image related to said optical image.

199. (canceled).

200. (Original) A method of forming a photo sensor comprising:

excavating a trench within a semiconductor substrate, said trench having a substantially vertical internal surface region;

performing a first ion implantation into said substantially vertical internal surface region at a first ion implantation angle;

performing a second ion implantation into said substantially vertical internal surface region at a second ion implantation angle.

201. (Original) A method of forming a photosensor as defined in claim 199 wherein said first implantation angle is orthogonal to said second implantation angle.

202. (Original) A method of forming a photosensor as defined in claim 199 comprising: performing a further plurality of ion implantations at a respective plurality of ion implantation angles.

203. (Original) A method of forming a photosensor as defined in claim 199 applying a passivation layer above said substantially vertical internal surface region.

204. (Original) A method of forming a photosensor as defined in claim 203 wherein said passivation layer comprises silicon dioxide.

205. (Original) A method of forming a photosensor as defined in claim 203 wherein said passivation layer comprises Borosilicate glass.

206. (Original) A method of forming a photosensor as defined in claim 203 wherein said passivation layer comprises phospho-silicate glass.

207. (Original) A method of forming a photosensor as defined in claim 203 wherein said passivation layer comprises boron-phospho-silicate glass.

208. (Original) A method of forming a photosensor as defined in claim 203 further comprising chemical mechanical planarizing said passivation layer.

209. (Original) A method of forming a photosensor as defined in claim 199 wherein said excavating a trench comprises anisotropically etching said semiconductor substrate.